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LHC Potential for the Higgs Boson Discovery

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Abstract

The expected searches for the Higgs boson(s) of the Standard Model and its Minimal Supersymmetric extension with the CMS and ATLAS detectors at the LHC are discussed.

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1 Introduction

The CERN LHC collider is expected to start functioning in the near future allowing, within few years, the direct search for Higgs bosons in the full expected mass range. In this report, the LHC potential for the Higgs boson discovery is discussed in the framework of the Standard Model (SM) and its Minimal Supersymmetric extension (MSSM). In the SM Higgs mechanism, the Higgs boson mass $\mathrm{m_H}$ is a free parameter bounded from below to $\mathrm{m_H} > 114.4$ GeV/c^2 by the LEP results [1]. The MSSM contains five Higgs bosons: the lighter scalar h, the heavier scalar H, the pseudoscalar A and the two charged bosons $\mathrm{H}^{\pm}$. The MSSM parameter space is in general presented as a function of the pseudoscalar mass $\mathrm{m_A}$ and the ratio tanβ of the vacuum expectation values of the two Higgs doublets. The SUSY corrections to Higgs boson masses couplings come from the $\mathrm{t}/\tilde{\mathrm{t}}$ sector and at large tanβ from the $\mathrm{b}/\tilde{\mathrm{b}}$ sector. The size of the correction is particularly sensitive to the Higgsino mass parameter μ. For most of the LHC studies, the $\mathrm{m_h^{max}}$ scenario, used in the LEP studies, has been chosen and has the following parameter values: $\mathrm{M_2}$ = 200 GeV/c^2, μ = 200 GeV/c^2, $\mathrm{M_{SUSY}}$ = 1 TeV/c^2, $\mathrm{M_{\tilde{g}}}$ = 800 GeV/c^2 and $\mathrm{X_t} = 2\mathrm{M_{SUSY}}$. The value of the top mass is fixed to 175 GeV/c^2. The LEP measurements yield lower bounds of 91.0, 91.9 and 78.6 GeV/c^2 for the masses of the h/H, A and $\mathrm{H}^{\pm}$ bosons in the MSSM [2, 3], respectively. The excluded tanβ regions are for 0.5< tanβ < 2.4 in the maximal $\mathrm{m_h}$ scenario [2].

At tree level the h(H) mass is bound to be below(above) the Z boson mass but the radiative corrections, proportional to $\mathrm{m_{top}^4}$, bring the upper (lower) bound to a significantly larger value. The one loop and dominant two loop calculations, with the SUSY parameters listed above and with a top quark mass of 175 GeV/c^2, predict an upper bound of about 128 GeV/c^2 with maximal stop quark mixing [4].

This report summarises the expected CMS and ATLAS searches for the SM and MSSM Higgs bosons with the most important discovery channels. Detailed descriptions of the CMS and ATLAS detectors can be found in Refs. [5, 6]. In CMS, the calorimeters are located between the tracker and the superconducting coil. Other features of the CMS detector [5] are a strong 4T axial magnetic field, a multilayer muon system in the return yoke and a scintillating crystal electromagnetic calorimeter. The tracker, placed closest to the beam pipe, is made of fine-grained micro-strip and pixel detectors. In the ATLAS detector [6], the inner tracking system is placed inside a solenoid providing a 2T axial magnetic field. In this detector, the electromagnetic and hadron calorimeters are outside the solenoid. The muon measurements are performed with air-core-toroid muon spectrometers in the barrel and end-cap regions.

The Higgs boson production and decay are discussed in Section 2. The discovery potential for the SM and MSSM Higgs bosons is discussed and presented in Sections 3-5 and conclusions are given in Section 6.

2 Higgs boson production and decay

In the SM, the Higgs boson production is dominated by the gluon-gluon fusion $\mathrm{gg} \rightarrow \mathrm{H}$ process, mediated by top and bottom quark loops, over the full expected mass range $100 \lesssim \mathrm{m_H} \lesssim 1$ TeV/c^2. The QCD corrections for the $\mathrm{gg} \rightarrow \mathrm{H}$ process are large, with the next-to-leading (NLO) k factor ranging from 1.6 to 1.9 [7]. The weak gauge boson fusion (WBF) process $\mathrm{qq} \rightarrow \mathrm{qqH}$ has a cross sections lower by one order of magnitude than the $\mathrm{gg} \rightarrow \mathrm{H}$ process for light Higgs bosons but approaches that of the $\mathrm{gg} \rightarrow \mathrm{H}$ process for heavy Higgs bosons. In this process the energetic quaks jets, emitted in the forward directions, and the absence of significant jet activity in the central rapidities can be used to efficiently suppress the W/Z+jets and $\mathrm{t\bar{t}}$ backgrounds at the LHC [8]. The other production processes $\mathrm{q\bar{q}'} \rightarrow \mathrm{HW}$, $\mathrm{q\bar{q}} \rightarrow \mathrm{HZ}$, $\mathrm{gg/q\bar{q}} \rightarrow \mathrm{t\bar{t}H}$ and $\mathrm{gg/q\bar{q}} \rightarrow \mathrm{b\bar{b}H}$ can be also exploited and yield a background suppression through the identification of the associated b jets and through the reconstruction of W/Z or top masses.

In the mass range of $\mathrm{m_H} \lesssim 130$ GeV/c^2 the SM Higgs boson mainly decays to $\mathrm{b\bar{b}}$ and $\tau^+\tau^-$ pairs with branching fractions of ∼85% and ∼8%, respectively. The total decay width is below 1 GeV/c^2 for $\mathrm{m_H} \lesssim 200$ GeV/c^2, increasing to the size of the order of the mass for heavy Higgs bosons. Due to the small width, the $\mathrm{H} \rightarrow \gamma\gamma$ and $\mathrm{H} \rightarrow \mathrm{ZZ}^* \rightarrow 4\ell$ decay channels with very small branching fractions can yield excellent signatures at the LHC.

In the MSSM, the lighter scalar h is SM-like for $\mathrm{m_A} > \mathrm{m_h^{max}}$ (decoupling region), with production cross sections and decay partial widths close to those of the SM Higgs boson. At large tanβ, the couplings of the heavy neutral MSSM Higgs bosons to the W and Z bosons are strongly suppressed, while those to the down-type fermions are enhanced with increasing tanβ. The production of the H and A bosons proceeds mainly through the $\mathrm{gg} \rightarrow \mathrm{H/A}$ and $\mathrm{gg/q\bar{q}} \rightarrow \mathrm{b\bar{b}H/A}$ processes. At large tanβ, the $\mathrm{b\bar{b}H/A}$ associated production dominates and presents about 90% of the total rate for tan$\beta \gtrsim 10$ and $\mathrm{m_A} \gtrsim 300$ GeV/c^2. If the charged Higgs bosons are light, $\mathrm{m_{H^\pm}} < \mathrm{m_{top}}$, they are produced in the $\mathrm{t\bar{t}}$ events through the $\mathrm{t} \rightarrow \mathrm{H^\pm b}$ decay. Heavier ($\mathrm{m_{H^\pm}} \geq \mathrm{m_t}$) charged Higgs bosons are mainly produced in association of top quarks in the $\mathrm{gb} \rightarrow \mathrm{tH^\pm}$ process and in the NLO $\mathrm{gg} \rightarrow \mathrm{t\bar{b}H^\pm}$ process [9].

For the heavy neutral MSSM Higgs boson H and A, the branching fraction to $\tau^+\tau^-$ is about 10% and that to $\mu^+\mu^-$ about 3×10^{-4}. Light charged Higgs bosons ($m_{H^\pm} < m_{top}$) decay to $\tau\nu_\tau$ with an almost 100% branching fraction. For $m_{H^\pm} \gtrsim$ 200 GeV/c^2 the $H^\pm \to$ tb decay dominates at large tanβ while the $H^\pm \to \tau\nu_\tau$ branching fraction decreases and is about 10% for $m_{H^\pm} \gtrsim$ 400 GeV/c^2. At small tanβ, the branching fractions of the neutral and charged MSSM Higgs bosons to gauginos, when kinematically allowed, dominate and suppress the branching fractions to SM particles. The branching fraction for $A/H \to t\bar{t}$, however, reaches $\sim$ 70% at large m_A.

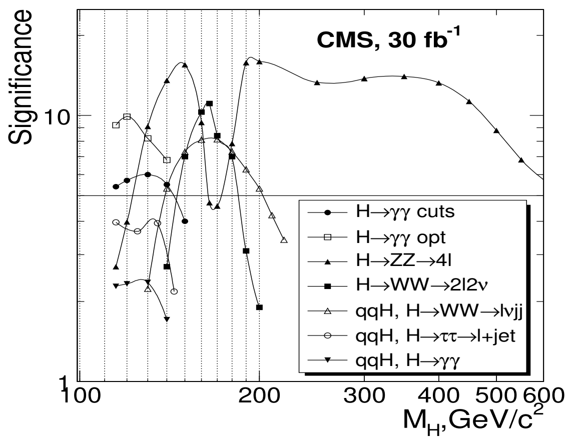

Figure 1: Expected statistical significance for the SM Higgs boson with 30 fb^{-1} of integrated luminosity as a function of m_H in CMS.

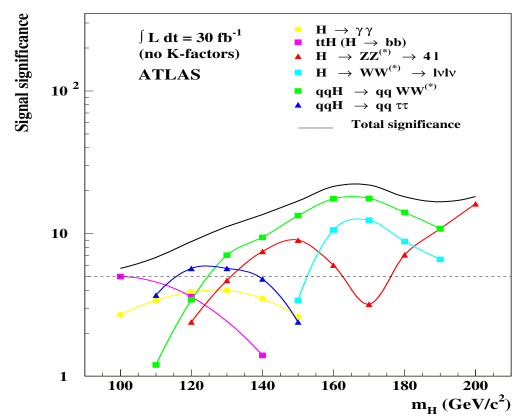

Figure 2: Expected statistical significance for the SM Higgs boson with 30 fb^{-1} of integrated luminosity as a function of m_H in ATLAS.

3 Searches for the SM Higgs boson

Figures 1 and 2 show the statistical significance for the SM Higgs boson in the most important discovery channels with an integrated luminosity of 30 fb^{-1} in the mass range of $100 \leq m_H \leq 800$ GeV/c^2 in CMS [10] and for $m_H \leq 200$ GeV/c^2 in ATLAS [11]. In the CMS analysis, NLO cross sections are used for the signal and background processes, and the significance is calculated according to Poisson statistics including the systematic uncertainties in the determination of all background components. The WBF channels play a significant role in the searches of a light SM Higgs boson. These channels have been proven particularly interesting for the Higgs boson coupling measurement and give the possibility of indirect total width measurement for $m_H < 200$ GeV/c^2 [12].

For the inclusive search of the $H \to \gamma\gamma$ channel there are large backgrounds from photon pairs produced from two initial gluons or quarks, from single photon production, where an associated jet fakes the photon signature, from multi-jet production, where two hadronic jets fake the photon signal, and from Drell-Yan production of electron pairs. The fake photon signals due to $\pi^0 \to \gamma\gamma$ decays in hadronic jets can be rejected with photon isolation and shower shape variables in the electromagnetic calorimeter. Two independent analysis have been performed for this channel in the recent CMS full simulation [10]. With a standard cut based analysis the Higgs boson can be discovered in this channel with a 5σ significance from the LEP lower limit to m_H = 140 GeV/c^2 with less than 30 fb^{-1} of integrated luminosity. With the optimised analysis with event by event estimation of the signal-to-background ratio this mass range can be covered with less than 16 fb^{-1} of integrated luminosity. The Higgs boson mass can be measured in the $H \to \gamma\gamma$ channel with a statistical precision of 0.1 to 0.2% already with 30 fb^{-1} of integrated luminosity. The expected mass measurement precision is shown in Fig. 3. The exclusive search of $H \to \gamma\gamma$ in the WBF and in the associated production channels $t\bar{t}H$, WH and ZH yield better signal-to-background ratios but require larger integrated luminosities, in excess of 100 fb^{-1}, for a significant signal [10].

Backgrounds for the four-lepton final state in the $H \to ZZ^*/ZZ \to \ell^+\ell^-\ell'^+\ell'^-$ signal are from the ZZ^*, $t\bar{t}$ and $Zb\bar{b}$ production and can be efficiently suppressed with lepton isolation in the tracker and in hadron calorimeter, an upper bound on the lepton impact parameter significance and cuts on the di-lepton invariant masses [10][11]. Discovery in the four-lepton channel is possible already with 10 fb^{-1} for the mass ranges of $140 < m_H < 150$ GeV/c^2 and $190 < m_H < 400$ GeV/c^2 in CMS, with similar reach in the ATLAS detector [11]. For 30 fb^{-1} the discovery range would open to $130 < m_H < 500$ GeV/c^2, apart the point around $m_H \sim 170$ GeV/c^2, which would require an integrated luminosity of 100 fb^{-1}. The Higgs boson mass can be measured in the $\mathrm{H} \rightarrow \mathrm{ZZ}^{*}/\mathrm{ZZ} \rightarrow \ell^{+}\ell^{-}\ell'^{+}\ell'^{-}$ channel with a precision of 0.1 to 5.4%, depending on the mass, with 30 fb^{-1} of integrated luminosity [10], as shown in Fig. 3. The intrinsic Higgs boson width can be measured, for the masses greater than 190 GeV/c^2, with a precision of ∼35%, and the production cross section can be determined with a precision of ∼30% [10]. The $\mathrm{H} \rightarrow \mathrm{ZZ} \rightarrow \mathrm{e}^{+}\mathrm{e}^{-}\mu^{+}\mu^{-}$ channel can be used to determine the CP properties of the Higgs boson [10].

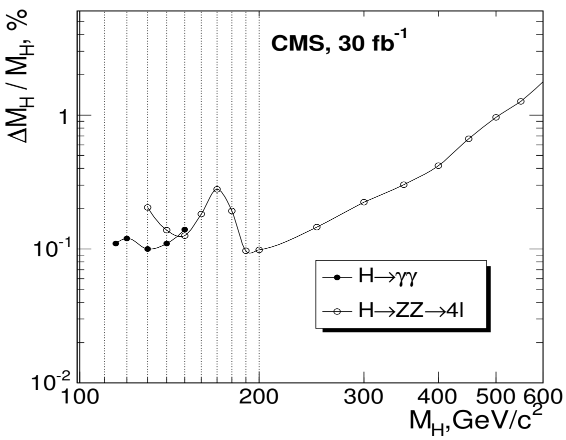

Figure 3: Expected precision of Higgs boson mass measurement in the $\mathrm{H} \rightarrow \gamma\gamma$ and $\mathrm{H} \rightarrow \mathrm{ZZ}^{*}/\mathrm{ZZ} \rightarrow \ell^{+}\ell^{-}\ell'^{+}\ell'^{-}$ channels in CMS with 30 fb^{-1} of integrated luminosity.

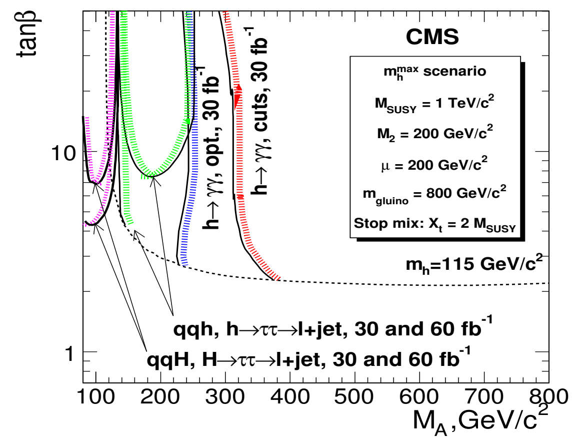

Figure 4: The 5σ-discovery potential for the lighter scalar MSSM Higgs bosons h with the $\mathrm{h} \rightarrow \gamma\gamma$ and $\mathrm{h} \rightarrow \tau^{+}\tau^{-} \rightarrow \ell + \mathrm{jet}$ decay modes as a function of $\mathrm{m_A}$ and tanβ in the $\mathrm{m_h^{max}}$ scenario with 30 and 60 fb^{-1} of integrated luminosity in CMS.

Around $\mathrm{m_H} \sim 170$ GeV/c^2, where the $\mathrm{H} \rightarrow \mathrm{ZZ}^{*}/\mathrm{ZZ}$ branching fraction is smallest, the $\mathrm{H} \rightarrow \mathrm{WW}^{*}/\mathrm{WW}$ channel can be exploited [10, 11]. For $\mathrm{m_H} \lesssim 200$ GeV/c^2, the backgrounds are from the processes $\mathrm{q\overline{q}} \rightarrow \mathrm{WW} \rightarrow 2\mu 2\nu$, $\mathrm{gg} \rightarrow \mathrm{t\bar{t}} \rightarrow 2\mu 2\nu$ and $\mathrm{q\overline{q}} \rightarrow \gamma^{*}/\mathrm{Z} \rightarrow 2\mu$. The $\mathrm{t\bar{t}}$ background is reduced with muon isolation cuts and with a veto on central jets while a cut in the missing transverse energy and in the invariant mass of the muon pair have been used to suppress the $\mathrm{Z} \rightarrow \mu\mu$ background. The WW background can be reduced by taking advantage of WW spin correlations, which turn into small $\ell^{+}\ell^{-}$ opening angles for the signal. Including a detailed evaluation of background uncertainties, discovery is possible in this channel for $150 < \mathrm{m_H} < 180$ GeV/c^2 with greater than 5σ significance with less than 10 fb^{-1} of integrated luminosity. More efficient background suppression of the same decay mode, but with the $\ell\nu$jj final state, can be obtained in the WBF production process. In this channel the Higgs boson mass can be reconstructed determining the neutrino momentum from the missing transverse energy with the W mass constraint.

In the SM, the $\mathrm{H} \rightarrow \tau^{+}\tau^{-}$ decay mode with the subsequent $\tau_1 \rightarrow \mathrm{hadrons} + \nu_\tau$ and $\tau_2 \rightarrow \ell + \nu_\tau \nu_\ell$ decays can be searched for in the WBF production. In addition to the forward jet tagging cuts, the methods of hadronic τ identification and Higgs boson mass reconstruction from leptonically or hadronically decaying τ's are exploited in this channel. Isolation of the narrow τ jet, mainly performed in the tracker, has been proven the most powerful method against the hadronic jet background [13]. Further suppression can be obtained from track counting in the jet, $\mathrm{p_T}$ cuts for the tracks, impact parameter cuts for the tracks, secondary vertex reconstruction for the 3-prong τ decays and τ mass reconstruction with the calorimeter information [13]. The Higgs boson mass can be reconstructed in the $\mathrm{H} \rightarrow \tau^{+}\tau^{-}$ channels from the missing transverse energy and the visible τ momenta exploiting the neutrino collinearity with the parent τ direction. The mass resolution improves for a decreasing opening angle between the two τ directions and is sensitive to the precision of the missing transverse energy measurement. For 60 fb^{-1} of integrated luminosity a significance greater than 5σ can be obtained for $\mathrm{m_H} < 140$ GeV/c^2 with the $\mathrm{H} \rightarrow \tau^{+}\tau^{-} \rightarrow \ell + \mathrm{jet}$ channel.

4 Searches for the neutral MSSM Higgs bosons

Figure 4 shows the expected 5σ-discovery potential of CMS for the lighter scalar MSSM Higgs boson h in the most important discovery channels $\mathrm{h} \rightarrow \gamma\gamma$ and $\mathrm{h} \rightarrow \tau^{+}\tau^{-} \rightarrow \ell + \mathrm{jet}$ with 30 and 60 fb^{-1} of integrated luminosity.

The results are shown in the the m_h^{max} scenario. In the parameter space outside the LEP reach the lighter scalar Higgs boson is largely SM-like and the discovery channels are closely the same as for the light SM Higgs boson. The enhancement of the Higgs coupling to down type fermions renders the $h \to \tau^+\tau^-$ decay channel in the WBF process particularly interesting in the MSSM. In the decoupling region the m_A, tanβ-plane is covered with the $h \to \tau^+\tau^- \to \ell + \mathrm{jet}$ channel while the region of small m_A is covered with the SM-like heavy scalar in $H \to \tau^+\tau^- \to \ell + \mathrm{jet}$, also shown in Fig. 3.

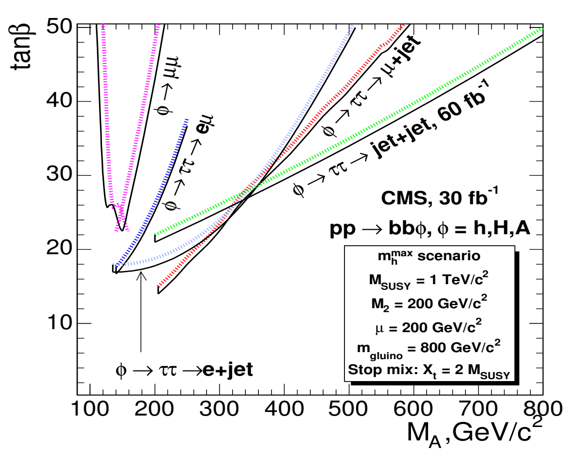

Figure 5: The 5σ-discovery potential for the heavy neutral MSSM Higgs bosons with the $H/A \to \mu^+\mu^-$ and $H/A \to \tau^+\tau^-$ decay modes as a function of m_A and tanβ in the m_h^{max} scenario with 30 and 60 fb^{-1} of integrated luminosity in CMS.

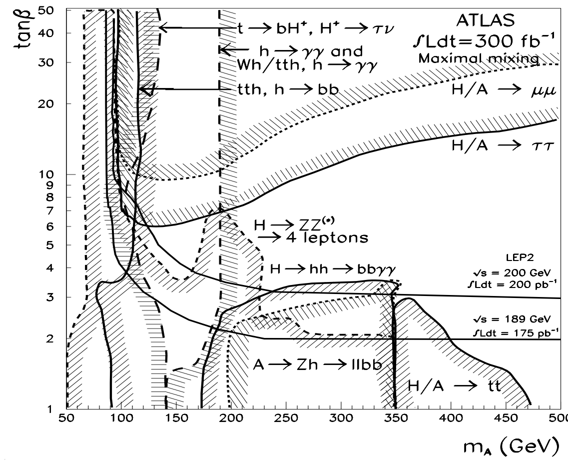

Figure 6: The 5σ-discovery potential for the neutral MSSM Higgs bosons as a function of m_A and tanβ in the m_h^{max} scenario with 300 fb^{-1} of integrated luminosity in ATLAS.

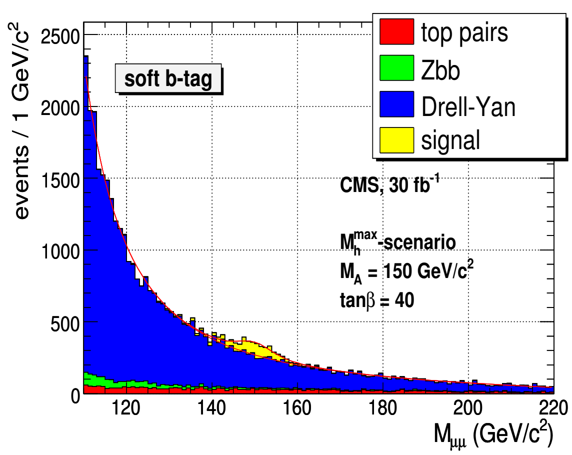

Figure 7: Invariant mass distribution for the $H/A \to \mu^+\mu^-$ signal with tanβ = 40 and m_A = 150 GeV/c^2, and for the total background with with 30 fb^{-1} integrated luminosity.

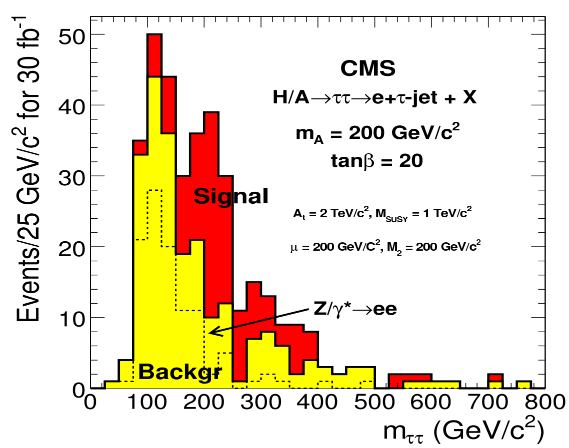

Figure 8: Invariant mass distribution for the $H/A \to \tau^+\tau^- \to$ electron + jet signal with tanβ = 20 and m_A = 200 GeV/c^2 and for the total background with 30 fb^{-1} integrated luminosity.

At large tanβ, the coupling enhancement to down-type fermions can be exploited to search the H and A bosons in the $H/A \to \mu^+\mu^-$ and $H/A \to \tau^+\tau^-$ decay channels in the associated production $gg \to b\bar{b}H/A$. In this production process, the tagging of the associated b jets suppresses efficiently the Z/γ^* and QCD multi-jet backgrounds. As the associated jets are not produced at high E_T scales and are emitted largely to forward rapidities, only one jet is tagged. The signal efficiencies are typically ~20% for a hadronic jet rejection of about 100. The $t\bar{t}$ and Wt backgrounds with genuine b jets can be suppressed with a veto on an additional central jet.

Figures 5 and 6 show the expected 5σ-discovery potential of CMS [10] and ATLAS [11] for the heavy neutral MSSM Higgs bosons with the $\mathrm{H/A} \to \tau^+\tau^-$ and $\mathrm{H/A} \to \mu^+\mu^-$ decay modes. The CMS discovery potential is shown for 30 fb^{-1} and 60 fb^{-1} of integrated luminosity while the the ATLAS reach is given for the expected ultimate LHC luminosity. The ATLAS reach includes several other discovery channels, like $\mathrm{A} \to \mathrm{ZH} \to \ell\ell\mathrm{bb}$, $\mathrm{H} \to \mathrm{hh} \to \mathrm{bb}\gamma\gamma$, $\mathrm{H,A} \to \mathrm{t\bar{t}}$, $\mathrm{H} \to \mathrm{ZZ}^* \to$ 4lepton and the discovery channels for the lighter scalar Higgs boson.

The branching fraction for the $\mathrm{H/A} \to \mu^+\mu^-$ decay mode is only small but this channel leads to a clean final state and a good Higgs boson mass reconstruction. At large $\tan\beta$ experimental mass resolution is comparable to the intrinsic Higgs boson width. Therefore the width measurement yields a constraint for the value of $\tan\beta$. For $\tan\beta = 40$, for instance, the uncertainty on the $\tan\beta$ measurement is from 17% to 25% for $150 \le \mathrm{m_A} \le 200$ GeV/c^2, including the theoretical uncertainty in the production rate. Figure 7 shows the invariant mass distribution for the $\mathrm{H/A} \to \mu^+\mu^-$ signal with $\tan\beta = 40$ and $\mathrm{m_A} = 150$ GeV/c^2, and for the total background with 30 fb^{-1} integrated luminosity.

The $\mathrm{H/A} \to \tau^+\tau^-$ decay channels can be searched for with the fully hadronic 2jets, electron+jet, μ+jet and two-lepton final states. The fully hadronic $\mathrm{H/A} \to \tau^+\tau^- \to$ 2jets+X channel is particularly challenging experimentally due to the obligation to use a fully hadronic trigger and the need to suppress the very large hadronic multi-jet background [10]. The Higgs boson mass can be reconstructed and a visible signal is reached within the expected discovery range. Figure 8 shows the invariant mass distribution for the $\mathrm{H/A} \to \tau^+\tau^- \to \mathrm{electron} + \mathrm{jet}$ signal with $\tan\beta = 20$ and $\mathrm{m_A} = 200$ GeV/c^2, and for the total background with 30 fb^{-1} integrated luminosity. The discovery potential in Fig. 5 is shown for the $\mathrm{m_h^{max}}$ scenario with $\mu = 200$ GeV/c^2. Combined effect from the supersymmetric radiative corrections and decay modes into supersymmetric particles has been shown to be a a shift of the discovery contours toward lower $\tan\beta$ values for negative values of μ. This shift is significant for large $\mathrm{m_A}$ ($\gtrsim$ 300 GeV/c^2).

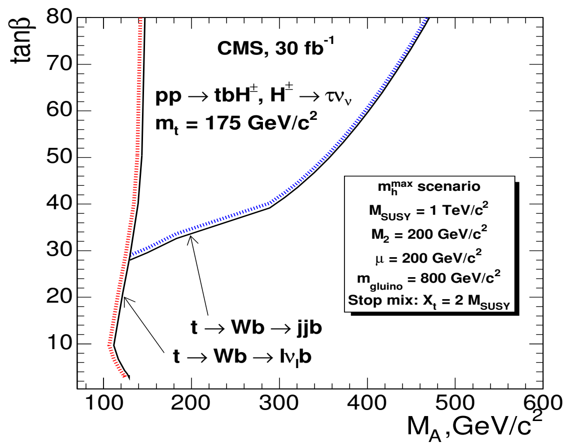

Figure 9: The 5σ-discovery potential of CMS for the charged MSSM Higgs bosons with the $\mathrm{H}^\pm \to \tau\nu_\tau$ decay mode as a function of $\mathrm{m_A}$ and $\tan\beta$ in the $\mathrm{m_h^{max}}$ scenario with 30 fb^{-1} of integrated luminosity.

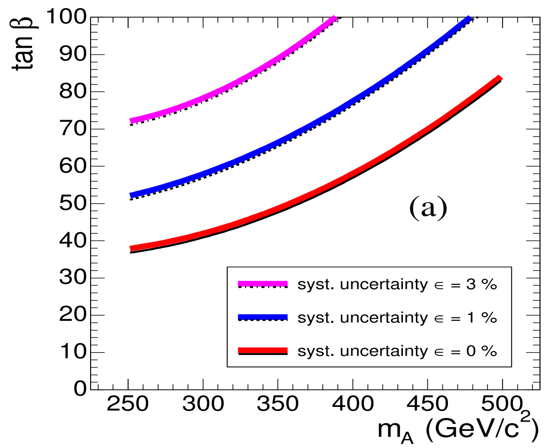

Figure 10: The 5σ-discovery potential of CMS for the charged MSSM Higgs bosons with the $\mathrm{H}^\pm \to \mathrm{tb}$ decay mode as a function of $\mathrm{m_A}$ and $\tan\beta$ in the $\mathrm{m_h^{max}}$ scenario with 30 fb^{-1} of integrated luminosity.

5 Searches for the charged MSSM Higgs bosons

Figures 9 and 10 show the expected 5σ-discovery potential of CMS [10] for the charged MSSM Higgs bosons with the $\mathrm{H}^\pm \to \tau\nu_\tau$ and $\mathrm{H}^\pm \to \mathrm{tb}$ decay channels for a 30 fb^{-1} integrated luminosity. A similar reach has been obtained for the $\mathrm{H}^\pm \to \tau\nu_\tau$ decay channels in the ATLAS experiment [11].

To search for the heavy charged Higgs bosons the $\mathrm{H}^\pm \to \tau\nu_\tau$ decay channel with hadronic τ decays can be used in the $\mathrm{t\bar{t}}$ events in the region $\mathrm{m_{H^\pm}} < \mathrm{m_{top}}$ and in the associated production process $\mathrm{gb} \to \mathrm{tH}^\pm$ for $\mathrm{m_{H^\pm}} > \mathrm{m_{top}}$. In these channels, the $\mathrm{t\bar{t}}$, Wt and W+3jet backgrounds with genuine τ's can be suppressed exploiting the opposite τ helicity correlations in the $\mathrm{H}^\pm \to \tau\nu_\tau$ and the $\mathrm{W}^\pm \to \tau\nu_\tau$ decays [14]. These correlations lead to a more energetic leading pion in the signal process from the $\tau \to \pi^\pm + \nu_\tau$ decay and from the longitudinal components of the 3-prong decay channels through ρ and a_1 mesons. A large background suppression can be obtained requiring at least 80% of the visible τ-jet energy to be carried by a single charged pion. For $m_{H^\pm} < m_{top}$, the $H^\pm$ signal is obtained from an excess of τ's in $t\bar{t}$ events relative to electrons and muons. This channel is expected to be triggered on a lepton from the decays of one of the top quarks. For $m_{H^\pm} > m_{top}$, in the purely hadronic events with hadronic top decays, the missing transverse energy originates mainly from the $H^\pm \to \tau\nu_\tau$ decay, making possible a reconstruction of the transverse mass from the τ jet and missing transverse energy with an endpoint at $m_{H^\pm}$ for the signal and at m_W for the backgrounds with the $W^\pm \to \tau\nu_\tau$ decay.

The dominating $H^\pm \to tb$ decay channel can be used in the associated $gb \to tH^\pm$ production process, with a leptonic decay of one the top quarks. The channel is a subject to a large background from the $t\bar{t}$ production with associated standard jets or b jets. Due to systematic uncertainties in the determination of this background no discovery is expected in the CMS detector with this decay channel for low ($\leq$ 60 fb^{-1}) integrated luminosities [10]. Methods of tagging three b jets, exploiting the $gb \to tH^\pm$ process, and tagging four b jets, selecting the NLO $gg \to tbH^\pm$ process, were used. Figure 10 shows the change in the expected discovery range when the systematic uncertainties are included for the $gb \to tH^\pm$ production process.

6 Conclusions

The most important channels for the searches of the Higgs bosons at the LHC in the SM and in its Supersymmetric extension MSSM were discussed. The SM Higgs boson is expected to be found at the LHC with several decay channels over the full expected mass range with the CMS and ATLAS detectors. In the region 140 GeV/$c^2 \lesssim m_H \lesssim$ 400 GeV/c^2 the discovery is possible already with an integrated luminosity of 10 fb^{-1} or less with the $H \to WW^*/WW$ and $H \to ZZ^*/ZZ$ decay channels. The inclusive $h \to \gamma\gamma$ channel can also yield a discovery already with 10 fb^{-1} of integrated luminosity from the LEP limit to $m_H \lesssim$ 150 GeV/c^2. The weak boson fusion production channels have been investigated, as a particular scope the Higgs boson coupling measurement. The $H \to WW^* \to \ell\nu jj$ decay channel leads to a 5σ signal already 30 fb^{-1} of integrated luminosity within 150 GeV/$c^2 \lesssim m_H \lesssim$ 200 GeV/c^2 while the $H \to \gamma\gamma$ and $h \to \tau^+\tau^-$ decay channels require larger integrated luminosity in the SM. The Higgs boson mass can be measured with a precision of 0.1 to 5.4% depending on the mass. The total decay width and the production rate can be measured with the precisions of ∼35 and ∼30%, respectively.

In the MSSM, a significant fraction of the parameter space is covered with the lighter scalar Higgs boson with the inclusive $h \to \gamma\gamma$ channel and with the $h \to \tau^+\tau^-$ channel in the gauge boson fusion $qq \to qqh$ already with 30 fb^{-1} of integrated luminosity. For 60 fb^{-1} of integrated luminosity only a small area around 130 GeV/$c^2 \lesssim m_A \lesssim$ 140 GeV/c^2, not yet excluded by LEP,is left uncovered. The heavy neutral MSSM Higgs bosons can be found through the $H/A \to \mu^+\mu^-$ and $H/A \to \tau^+\tau^-$ decays channels at large tanβ. The two-lepton and lepton+jet final states from the $H/A \to \tau^+\tau^-$ decays cover the domain $m_A \lesssim$ 300 GeV/c^2 and tan$\beta \gtrsim$ 10 already with 30 fb^{-1}. The two-τ-jet final states extend the sensitivity up to $m_A \sim$ 800 GeV/c^2 for tanβ values larger than 25 for 60 fb^{-1} of integrated luminosity. The heavy scalar H can be discovered in the $H \to \tau^+\tau^-$ decay channel also in the gauge boson fusion for $m_A \lesssim$ 120 GeV/c^2 and tan$\beta > 8$ already with 30 fb^{-1}. For the searches of the charged Higgs bosons the $H^\pm \to \tau\nu_\tau$ decay channel with hadronic τ decays plays a crucial rule. For $m_{H^\pm} < m_{top}$ the reach is for $m_A \lesssim$ 140 GeV/c^2 in the $t\bar{t}$ events with leptonic decay of one of the top quarks. The heavy charged Higgs bosons can be found at large tanβ ($\gtrsim$ 30) with this decay channel in the associated production with top quarks in fully hadronic final states.

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